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Measuring the rebound effect with micro data: A first difference approach[☆]

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ABSTRACT

We provide estimates of the rebound effect for car transport in Denmark, using a rich data set with individual household data on car use, fuel efficiency, and car as well as household characteristics. A demand model is estimated in first differences; the availability of households in the sample that replaced their car during the period of observation combined with information on their driving behaviour before and after the car switch allows us to identify the rebound effect. Endogeneity is taken into account by using appropriate instruments. Results include the following. First, we reject the 'conventional' formulation in which only fuel cost per kilometre matters. Second, the selection equation confirms that higher fuel prices induce households to switch car. Third, the results suggest the presence of a rebound effect that is on the lower end of the estimates available in the literature. Specifically, our best estimate of the rebound effect is some 7.5–10%. Fourth, the fuel price sensitivity of the demand for kilometres appears to be declining with household income, but we do not find a significant impact of income on the rebound effect. Finally, simulation results indicate that the small rebound effect and changes in car characteristics in response to higher fuel prices imply that – compared to the reference scenario – higher fuel prices lead to a substantial reduction in both the demand for kilometres and in demand for fuel.

Introduction

Car fuels contribute substantially to carbon emission and local air pollution (see, e.g. Knittel, 2012). One way to reduce these external effects is to stimulate or enforce efficiency standards such as those imposed by CAFE in the USA. However, it is well known that consumer responses to improved energy-efficiency of energy-intensive devices induce a 'rebound' effect. Better energy-efficiency reduces the unit cost of using the device, so that optimizing behaviour by users implies that some of the energy savings and reduced emissions that would have been realized with unchanged behaviour are foregone. Of course,

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this diminishes the effectiveness of such improvements. The rebound effect has a long history in several energy-intensive sectors. Surveys are provided in, among others, Greening et al. (2000) and Sorell et al. (2009).

Recently, environmental concerns in the transportation industries have generated widespread interest in the rebound effect for car transport, capturing the impact of improved fuel efficiency on the demand for kilometres driven. This is not surprising, as the effectiveness of the corporate average fuel efficiency (CAFE) standards in the US and the weight-based fuel efficiency standards in the EU may strongly depend on the size of this effect. Quite a few papers have therefore explicitly focused on the transport sector, and a fair number of estimates of the rebound effect for car transport – some using aggregate data, others individual household information – are now available in the literature.[1] For example, in an early study Greene et al. (1999) used US household data over the period 1979–1994 and estimated the rebound effect at 17–28%. In a seminal paper, Small and Van Dender (2007) reconsider the rebound effect in the context of a set of aggregate simultaneous equations (demand for car stock, demand for mileage, and demand for fuel efficiency), using aggregate panel data for U.S. states over the period 1966–2001.[2] They evaluate the rebound effect at 4.5% in the short run and more than 20% in the long run. That is, 4.5% of the fuel savings implied by an increase in fuel efficiency under the *ceteris paribus* condition is retaken immediately by a change in driver behaviour, and in the course of time this increases to over 20%. The authors find substantially lower values, some 11%, for the more recent years (1997–2001) in their study period, which they attribute to higher incomes. Hymel et al. (2010) extend earlier results using a larger data set, further exploring the role of income and the potential importance of congestion in explaining the decline in the rebound effect.[3] Based on individual household data for the US, Linn (2013) recently relaxes several implicit assumptions in earlier studies and reports estimates in the range of 20–40%. Remarkably, in some European countries much higher values have been reported. For example, Frondel et al. (2008) and Frondel and Vance (2012) estimate the rebound effect on German panel data, producing very large rebound effects of up to 60%. Finally, Weber and Farsi (2014) use Swiss data to estimate a simultaneous equation system that accounts for endogeneity of distance, fuel intensity and vehicle weight; they report rebound effects of almost 75%.

Of course, the interest of policy makers is primarily in the aggregate, system-wide rebound effect, so that aggregate studies of the rebound effect are quite valuable. However, as the phenomenon originates at the level of the individual actors, it seems appropriate to evaluate the responses of car users to fuel prices and fuel efficiency using individual household data. The purpose of this paper is to study the rebound effect of an increase in the fuel efficiency of cars, using a detailed and especially rich panel data set on individual households in Denmark for the period 2001–2011, paying careful attention to endogeneity and selection issues. Our focus is on the ‘direct’ rebound effect, the effect of better fuel efficiency on demand for kilometres driven. This is not to downplay the possible additional effects that can be associated with the more intensive use of cars, but it helps to focus on what we regard as the most important issue; moreover, it facilitates direct comparison with previous literature.[4] We further use the estimates to simulate the implications of fuel price increases.

Central to the analysis is a demand equation for car kilometres in which the fuel price per kilometre and fuel efficiency are the main explanatory variables of interest; the coefficients for fuel price and fuel efficiency are allowed to differ. Contrary to earlier studies based on individual data, we estimate the demand equation in first differences for households replacing their car; this has the advantage of fully controlling for unobserved factors that remain constant over time.[5] To do so, we use data on almost 350,000 observations on single car families, covering a period of ten years (2001–2011). To estimate the rebound effect in our first difference model, we split the sample period in three subperiods. Based on odometer readings we derive information about the numbers of kilometres driven in the first and the third subperiod, allowing us to consider the change between the two periods. Moreover, by distinguishing households that replaced their car during the mid-period of observation, we can precisely measure the impact of the switch of cars and the associated change in fuel efficiency on the demand for kilometres. Of course, in such a demand analysis endogeneity of fuel efficiency (of the new car) is an important concern, because households may replace their car because they expect to drive more or less in the future. We deal with endogeneity of car characteristics by using instrumental variables; the instruments used are the characteristics of the old car relative to the average Danish car. We also model the decision to replace cars using a Heckman selection model, incorporating the occurrence of car accidents – based on individual information – and the length of car ownership as additional identifying variables.

This paper contributes to the literature in several ways. First, the availability of a unique data set allows us, unlike previous studies, to estimate the demand equation in first differences. Second and relatedly, our measurement of the rebound effect has the advantage that it is purely based on changes in fuel efficiency when households switch to a new car,

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[1] A few studies have attempted to estimate the rebound effect using freight transport data (see, for example, De Borger and Mulalic (2012)).

[2] Barla et al. (2009) use similar techniques based on aggregate data for Canadian provinces.

[3] Very recently, Hymel and Small (2014) find the rebound effect to be asymmetric: it is larger in periods of fuel price increases than in years when fuel prices decline.

[4] The recent literature (see, for example, Borenstein (2013)) distinguishes direct, indirect, re-spending and transformational rebound effects. The indirect effect is defined as the increased energy consumption from changes in the use of other energy-using products than the one where the improvement occurs. A responding effect occurs when the money saved by improved fuel efficiency is spent on other goods that use fuel (for example, spend less on gasoline but buy an extra plane ticket). For more details, see Borenstein (2013). The numerical example on page 19–21 of Borenstein (2013) gives an impression of the magnitude of the wider effects of car fuel efficiency improvement. See also Gillingham et al. (2014) for a discussion of the wider effects of a change in energy efficiency of a device.

[5] Determining the rebound effect based on changes within households over time makes the analysis less susceptible to problems of spurious correlation than earlier studies focusing on a single cross section.